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NEODYMIUM LASER GLASS
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American Optical Corporation
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FOREWORD

This report has been prepared by the Central Research Laboratory of the American Optical Corporation, Southbridge, Massachusetts under Contract Nonr 3835(00) entitled "Neodymium Laser Glass Improvement Program." The contract is under the sponsorship of the Office of Naval Research and this report covers the six-month period ending 31 December 1966.

Dr. Richard F. Woodcock is project manager and author of this report.

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ABSTRACT

Determination of the thermal coefficient of refractive index was begun on the second generation of athermal glass compositions and results are encouraging. The procedure for measuring stress-optical coefficients was reviewed and a more refined technique for applying pressure to the sample is under investigation. Improvements in glass quality required for some of the property measurements have been obtained.

NEODYMIUM LASER GLASS IMPROVEMENT PROGRAM

1. INTRODUCTION

This report is a technical summary covering work performed during the period 1 July 1966 - 31 December 1966 on Amendment No. 3 of Contract Nonr-3835(00) entitled "Neodymium Laser Glass Improvement Program." The expiration date of this contract was 30 April 1966. As previously reported, a time only extension was requested with a termination date of 31 July 1966. A request for a 12 month extension of funded effort has since been made. This was granted in the form of Amendment No. 4 to this contract received in late December 1966, effective as of 21 November 1966 with the termination date extended to 31 July 1967. Work has continued during this six month period, but at a reduced level of effort.

2. ATHERMALIZATION STUDIES

Measurements of the coefficient for the change in optical thickness as a function of temperature, α_T, and the thermal expansion coefficient, α, of the second generation of athermal glass compositions based on MG-1750 [Ref.: Technical Summary Report No. 8, Contract No. Nonr-3835(00)] were initiated during this period. Measured values of α_T (average value for the temperature range between 25 and 125°C) and measured values of α (average value for the temperature range between 25°C and 300°C) obtained to date are listed in Table I, together with a preliminary value of α_n, the thermal coefficient for refractive index calculated, in this case, by taking the difference between the tabulated values of α_T and α. Tentative values of the athermalization figure-of-merit, α_n/α, are also included in Table I. These values are considered to be tentative because they are based on average values of α_T and α. Additional compositions in this series are in the process of being measured. A comparison of the tentative values of α_n/α given in Table I with those reported previously [Ref.: Technical Summary Report No. 7, Contract No. Nonr-3835(00)] indicates that some of the compositions in this new series may be better candidates for an athermalized laser system than any of the previous compositions.

Table I

Glass Number	α_T	α	α_n	α_n/α
1897	88.5	97.8	-9.3	-0.09
1898	75.3	99.3	-24.0	-0.24
1899	68.7	111.9	-43.2	-0.39
1903	79.5	111.3	-31.8	-0.29
1907	88.4	121.9	-33.5	-0.27
1911	75.5	125.0	-49.5	-0.40
1917	81.7	133.0	-51.3	-0.39
1918	70.0	130.0	-60.0	-0.46
1919	99	130.0	-31.0	-0.24

An attempt was made to obtain some idea of the degree of accuracy being achieved in the measurement of the stress-optical coefficients $B_\perp$ and $B_\parallel$ that have been made to date on glass samples of reasonably good optical quality. This was done by calculating the relative stress-optical coefficient or stress birefringence, B, from these values ($B = B_\parallel - B_\perp$) and comparing this calculated value of B with values of B obtained by two independent experimental measurements of B. In one measurement, the retardation is measured with a Babinet compensator and the stress is determined by the Cornu-Straubel method. The second measurement is by the fiber method described in Tentative Procedure B of ASTM Test F218. Modest correlation was obtained between values of B found by these three methods only after several determinations had been made and some statistical analysis was applied to the results to determine the most probable correct value.

An attempt to solve the problems encountered in the determination of the stress-optical coefficient, particularly on glass samples containing some degree of striae, was made by using a holographic technique. We hoped that the resulting reconstruction would represent only the shift in fringes due to the applied

stress and not the fringes which are due to stria in the sample. To evaluate the technique, a holographic system was setup on a granite slab. Using a He-Ne laser as a source, double exposure holograms were made of the stressed and unstressed state of both striated and stria-free glass samples. The reconstructed image obtained from the hologram of the stria-free sample showed a series of smooth fringes. The reconstructed image of the striated sample, however, showed a rather complex fringe pattern which appeared to be no improvement over the patterns obtained with standard interferometric measurements. Further experimentation indicated that part of this problem is due to movement of the sample during the application of stress. An improvement in the measuring technique, particularly in the method of holding the sample during the application of stress, is still desired.

Present indications are that test specimens of better optical quality are required in many cases for both the determination of the elastic constants E and σ being made at MIT, and for the measurement of the stress-optical coefficients that we are making. An improved melting technique which uses slightly larger (two pound) melts has resulted in a considerable improvement in glass quality. These melts are polished on the top and bottom surfaces to allow examination of optical quality. Sections with acceptable optical quality are selected from which the test samples are taken. Remelts of previous athermal glasses will be made by this technique where necessary.

3. SUMMARY AND CONCLUSIONS

Determ nation of the thermal coefficient of refractive index is in progress and results to date on the second generation of athermal glass compositions are encouraging.

The procedure for measuring stress-optical coefficients is being thoroughly reviewed. A more refined technique for applying pressure to the sample without introducing motion to the sample is under investigation. Since this may constitute a major change in our measuring apparatus, serious consideration is also being given at this time to other interferometric methods which would be less sensitive to small amounts of stria in the test sample.

The concept of making an independent measurement of the relative stress-optical coefficient and using this as a check on the values obtained for $B_{\parallel}$ and $B_{\perp}$ appears to be a valid one

and will be incorporated into future measurements. This will probably be done with a Babinet Compensator on the same apparatus used to provide the stress in samples for the determination of the stress-optical coefficients.

Improvements in glass quality required for some of the property measurements have been obtained. Remelts of previous compositions will be made where necessary.